Bubbles in Sediments

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SHALLOW-WATER ACOUSTICS

LONG-TERM GOAL

This research investigated the scattering of an acoustic field from a bubble embedded in a saturated sediment. The primary objective was to establish the underlying physical mechanisms of resonance scattering near the breathing mode (or monopole) resonance.

SCIENTIFIC OBJECTIVES

Bubbles are known to be present in naturally occurring sediments particularly in littoral regions, and it has been proposed that these bubbles are primary contributors to volume scattering of sediment penetrating sonars.

APPROACH

The scattering from an isolated bubble in an infinite, isotropic, homogeneous sediment was analyzed where the sediment was modeled as either an effective fluid, effective viscoelastic solid, or a saturated poroelastic medium. The analysis included only the breathing mode resonance because this resonance dominates the dynamics of the bubble. The complexity of wave propagation in the choice of model for the sediments increases in the order given.

Based on the results of the theoretical treatment, a laboratory experiment has been designed to test which model provides a suitable characterization of the underlying wave propagation and scattering phenomenon. The experiment embeds a bubble in a synthetic, transparent sediment. This sediment is prepared by matching the optical indices of refraction of soda-lime glass beads, which represent grains of sand, and a saturating fluid. The forward extinction of a HeNe laser by an acoustically driven bubble is characterized by a modulations in the optical intensity. The frequency of modulation is directly related to the dynamics of the bubble.

WORK COMPLETED

To date, the theoretical treatment has been completed and documented[1]. A brief description of the main results are discussed below.

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Experimental verification of theoretical predictions has progressed to the measurement of the optical extinction. A synthetic transparent sediment has been constructed from nominally 300 micron glass beads obtained from Cataphote Inc. The beads are saturated with immersion liquid code 1160 from Cargille Laboratories Inc. Although the saturated beads are not perfectly clear to white light, an embedded bubble is visible and the principal laser line from a HeNe laser (632.8 nm) passes through a small volume without much loss. The experiment is scheduled to be completed in early FY98.

RESULTS

If a sediment can be characterized by an effective fluid model, then theory predicts a bubble will support a breathing mode resonance on the order of a few kHz in agreement with the well-known Minnaert resonance frequency. The viscoelastic solid model for a sediment predicts a much higher resonance frequency due primarily to the inclusion of shear rigidity in the model. It is noted that both an effective fluid model and an effective viscoelastic solid model predict a single breathing mode resonance, and the frequency of this resonance are widely separated for each model. Finally, if a sediment is modeled by Biot theory, which describes wave propagation in a saturated poroelastic medium, then two monopole resonances are predicted. These resonances appear to be an intrinsic property of Biot theory, and hence, can validate the application of Biot theory to sediment acoustics. The predicted resonance behavior under each model is distinct, so an optical extinction measurement may provide an unambiguous measure of which model(s) applies.

IMPACT/APPLICATION

Bubbles are known to occur in natural sediments. It is expected that the knowledge gained in this research will impact sediment penetrating sonar systems and the interpretation of images produced by these sonars.

TRANSITIONS

The present research will be extended from single isolated bubbles to multiple bubbles where multiple scattering becomes important. Additionally, the infinite medium assumption imposed to isolate the resonance behavior will be removed such that the bubble will be embedded in a plane stratified medium of arbitrary composition. These extensions are expected to transition into enhancement to sonar prediction tools such as the Shallow Water Acoustic Toolset (SWAT) available from the Coastal Systems Station, Dahlgren Division, Naval Surface Warfare Center.

RELATED PROJECTS

The current research has a potential impact on the Departmental Research Initiative (DRI) entitled "High-Frequency Sound Interaction in Ocean Sediments" under the sponsorship of ONR Code 321 Ocean Acoustics. The DRI is addressing the sub-critical penetration of sonars into sand sediments. One hypothesis for this penetration is the interaction of volume inhomogeneities with the evanescent field near the sediment-water interface.

REFERENCES

[1] S.G. Kargl, K.L. Williams, and R. Lim, "Double monopole resonance of a gas-filled, spherical cavity in a sediment," *J. Acoust. Soc. Am.*, in press.